Space Weather Technical Forecast

Issued on Friday, 01 December 2023 at 13:29 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G2-G3 Moderate to Strong storms expected at first, easing later day 1 (01 Dec). Chance of M-class flares (R1-R2 Blackouts).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with a peak flare of M1.1 at 01/0439 UTC from AR3502. There are currently ten sunspot regions on the visible disc with AR3500 the largest of these, located in the southwest. The region is comprised of numerous moderately sized spots with small umbrae. Two small and weak delta spots developed in the eastern cluster of spots and is currently classified as Eac/Beta-Gamma-Delta region. All other regions on the disc remain smaller and simpler, and generally either stable or showing signs of decay. However, AR3052 in the northwest produced the largest flare of the period. It appeared to undergo slight development of its trailer spots, although it is now approaching the western horizon and becoming increasingly difficult to assess.

There are a number of filaments on the Earth-facing disc. Two of these appeared to liftoff during the period, both of these from the southwest disc. One around 30/1700 UTC and the other at approximately 01/0600 UTC. Neither of these appear to have resulted in any notable CMEs in coronagraph imagery. Other CME signatures in coronagraph imagery during the past 24 hours are considered far-sided and thus not Earth-directed.

Solar Wind / Geomagnetic Activity: Solar wind speeds, as observed by ACE and DSCOVR at L1, were at Background levels, around 350km/s, until 30/2328 UTC when the speed jumped to 450 km/s (Slightly Elevated). This likely associated with the arrival of the CME from late 27 Nov. Speeds slowly declined to around 400km/s until 01/0850 UTC, when speeds suddenly increased to 500-560km/s (Elevated) as the 'full halo' CME from 28 Nov arrived at L1.

Density was below average until late in the UTC day on 30 Nov, then rapidly increased to around 20 ppcc (Above Average) with the arrival of the first CME. Density then became Average to Below Average for a time, before increasing as the second CME arrived, becoming Above Average, peaking at 23 pppc at 01/1056 UTC.

The Interplanetary Magnetic Field (IMF), Bt, was Weak until the first CME arrived, when the Bt jumped to Moderate levels. A peak just above 15nT at 01/0125 UTC allowed the IMF to become briefly Strong. Following the arrival of the second CME, Bt increased to more persistently Strong levels, peaking 28nT at 01/1004 UTC. The north-south component of the IMF (Bz), varied Weakly at first, then varied Moderately following the first CME. A stronger response was evident with the arrival of the second CME, becoming Strongly negative (peak -27nT at 01/1024 UTC) before easing to Weak or Moderately negative by the end of the period as the IMF underwent a slow, smooth rotation at L1 within the magnetic cloud. Phi angle was largely positive (away from the Sun).

Resultant Geomagnetic activity was Quiet (Kp 0-1) initially, increasing to Unsettled to Active (Kp3-4) between 01/0000-0900 UTC. Activity increased further to G3/Strong Storm levels 01/0900-1200 UTC.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux

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remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux was at Moderate levels (peak 394 pfu at 30/1915 UTC) but reduced to become Background following the arrival of the first CME at L1. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu) with a steady then slightly declining trend. The observation at 01/0000 UTC was 1.39e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate with a chance of further isolated M-flares (R1-R2 Blackout), and a very slight chance of an isolated X-class flare (R3 Blackout). AR3500 in the southwest disc is most likely to be the source of any significant flares.

Solar Wind / Geomagnetic Activity: The CME associated with the M9.8 flare of AR3500 on 28 Nov has arrived at Earth and strongly influenced solar wind parameters with speeds currently around 500-560km/s (Elevated). No further CME arrivals are expected during the period and solar wind speeds and magnetic field strength are generally expected to ease in the next few days, however Geomagnetic activity is expected to be strongly influenced by this CME in the coming 24 hour period.

Solar winds should ease to Slightly Elevated or Background levels in the next few days. The next HSS enhancement is expected late day 4 (04 Dec) or early 05 Dec. Elevated winds of around 500-550 km/s are likely from this feature, though the peak solar winds may just fall outside the scope of this current forecast period.

Geomagnetic activity has reached G3/Strong Storm levels. Activity should slowly wane during the first 24 hours, but with further G1-G2 Minor-Moderate Storm intervals likely at first. Activity should become Quiet to Unsettled during day 2 (02 Dec), remaining at similar levels until the arrival of the HSS late day 4 (04 Nov) or perhaps early 05 Dec (just outside the current forecast period). The onset of the HSS should see activity increase Active to G1/Minor Storm (Kp 4-5) levels.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels. However, any significant flares, mainly from AR3500, or any notable filament eruptions will bring a chance of flux levels increasing, with a slight chance of approaching or perhaps exceeding the S1 Minor Radiation Storm level.

Electron flux has fallen to Background levels following the arrival of recent CMEs in the past 24 hours. Some recovery of flux to Moderate or High levels at diurnal peak, is likely during day 3 (03 Dec), only to decrease to Background levels again as geomagnetic activity increases late day 4 (04 Dec) with the arrival of the a HSS.

The associated 24 hour electron fluence is expected to remain below the Active threshold (1e8 integrated pfu). However, a rising trend is likely from day 3 onward, once any CME influence recedes with a chance of exceeding the Active threshold on day 4.

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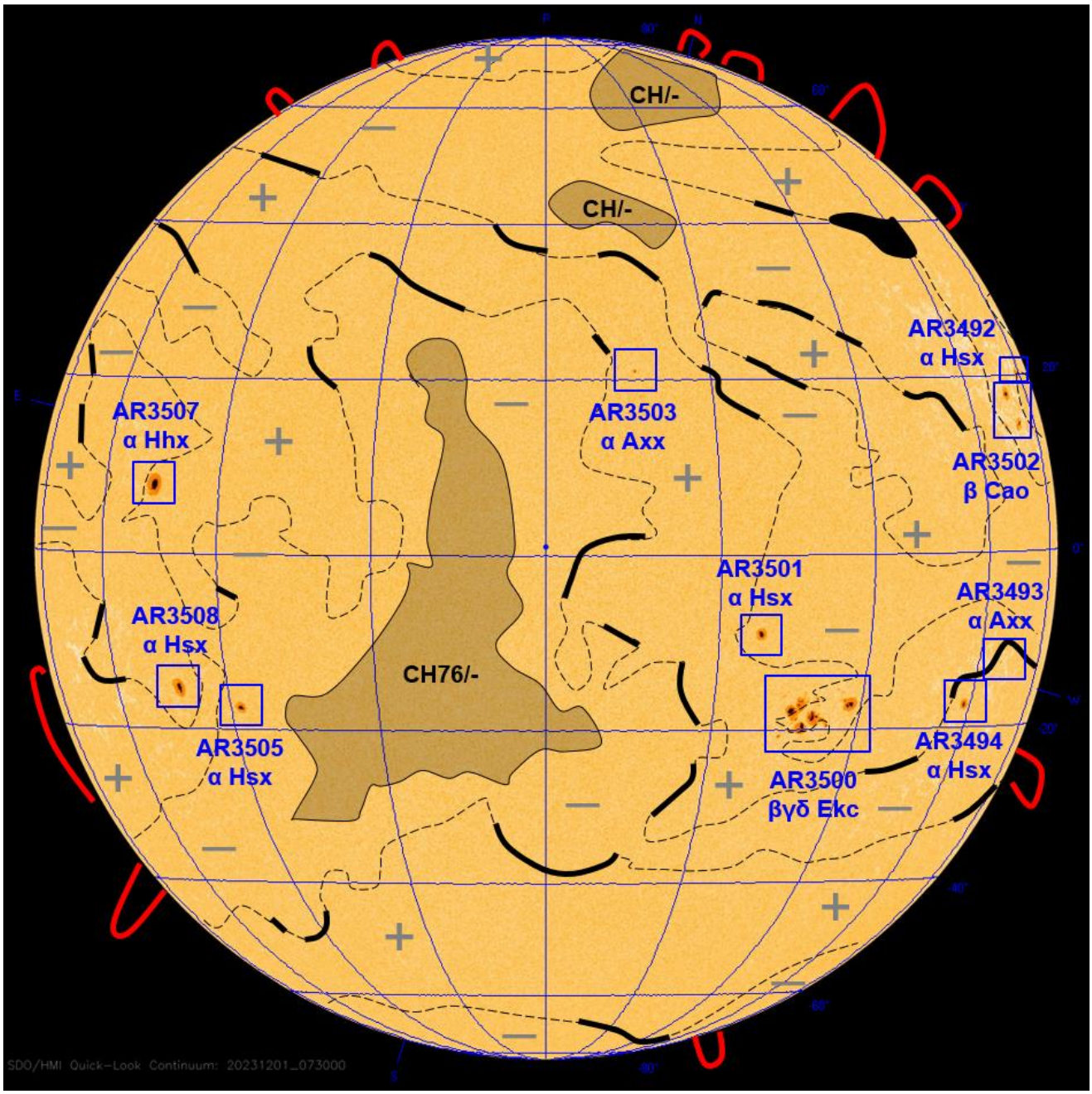
Figure 1. Solar Analysis Valid 01/0730 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The CME associated with the M9.8 flare of AR3500 on 28 Nov arrived at L1 at 01/0849 UTC and has since arrived at Earth. Solar wind speeds increased from around 400km/s (Slightly Elevated) to between 500-560km/s (Elevated) with an initially Strongly negative Bz observed, though has since become Strongly positive (as of around 01/1240 UTC). No further CME arrivals are expected during the period and solar wind speeds and IMF strength are expected to ease in the next few days, however Geomagnetic activity is expected to be strongly influenced by this CME in the next 24 hours.

Aside from the current CME, mainly Slightly Elevated to Background winds are forecast until late in the period when a High Speed Stream (HSS) from CH76/- is due to arrive. The expected onset of this feature is late day 4 (04 Dec) or early 05 Dec. CH76/- is a persistent feature, and is very similar in size and position to the previous rotation. In theory this would strengthen the use of persistence forecasting, but during the previous rotation a CME arrived, masking the influence of the coronal hole. Therefore the forecast Elevated winds, of around 500-550 km/s, have lower confidence than normal and potentially slightly faster winds may arrive.

Geomagnetic activity has reached G3/Strong Storm levels. Activity should slowly wane during the first 24 hours, but with further G1-G2 Minor-Moderate Storm intervals likely at first. Activity should become Quiet to Unsettled by 1200 UTC on day 2 (02 Dec), remaining at similar levels until the arrival of the HSS late day 4 (04 Nov) or perhaps early 05 Dec (just outside the current forecast period). The onset of the HSS should see activity increase Active to G1/Minor Storm (Kp 4-5) levels.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	100	30	1	50
Strong	G3	Yes	80	1	1	3
Severe	G4	No	5	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections - Nil

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Radio Blackouts - X-Ray Flares:

There are ten sunspots on the disc, with AR3490 having rotated out of view in the far northwest. AR3500 (Ekc/Beta-Gamma-Delta) in the southwest remains the largest and most significant region, but with little change in recent appearance. Two small and weak delta spots are observed in the eastern cluster of spots. However, despite the magnetic complexity this infers, the region has not produced the largest flare of the past 24 hours. The remaining regions on the visible disc are relatively small and simple, and predominantly mature and stable unipolar "H" spots. However, AR3502 remains classified as a Cao/Beta, while AR3493 has decayed and almost faded away.

Solar activity is at Moderate levels with the largest flare of the previous 24 hours an M1.1 flare peaking at 01/0439 UTC from AR3502 in the far northwest. Low to Moderate activity is expected with a chance of isolated further M-flares (R1-R2 Blackout), and a very slight chance of an isolated X-class flare (R3 Blackout). The bulk of the current flare risk is attributed to AR3500. This region should rotate off the visible disc on 05 Dec, just outside of the current forecast period.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	5	5	5	5

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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background and expected to remain at this level. However, with the number of spots and filaments on the disc, there is a chance of flux increasing in response to any significant flares or eruptions. The main risk is from AR3500, in the southwest disc. This was the source of an M9.8 flare late on 28 Nov, and while no proton response was observed at Earth on this occasion, any subsequent flares will also have the potential to increase the observed proton flux.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

Electron flux has fallen to Background levels following the arrival of recent CMEs in the past 24 hours. Some recovery of flux to Moderate or High levels at diurnal peak, is likely during day 3 (03 Dec), only to decrease to Background levels again as geomagnetic activity increases late day 4 (04 Dec) with the arrival of the HSS from CH76/-.

The associated 24 hour electron fluence is expected to remain below the Active threshold (1e8 integrated pfu), as supported by REFM. However, a rising trend is likely from day 3 onward, once any CME influence recedes with a chance of exceeding the Active threshold on day 4.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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Figure 2: GOES >2MeV Electron Flux (above) and MOSWOC Fluence forecast with recurrence (below)

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